Climate Observations from the Peru-Chile Stratus Deck

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Introduction

Initiated as part of the East Pacific Investigation of Climate (EPIC) in October 2000, a buoy with a suite of surface meteorological and upper ocean instrumentation was deployed at 20°S 85°W in the center of the dense stratus cloud decks off of South America. The stratus clouds overlie an anomalously cool ocean, and are thought to play an important role in maintaining the equatorial asymmetry in wind and SST. Climate models have suggested that stratus clouds increase in response to increases in CO_2, and can thus act to counter increases in temperature in the subtropical ocean. This is also the source region of high salinity mode water that flows directly onto the equator and may play a role in modifying equatorial currents on inter-annual time scales. Unfortunately, there is little observational basis for investigation of feedback mechanisms and the role of the eastern Pacific stratus decks in climate variability.

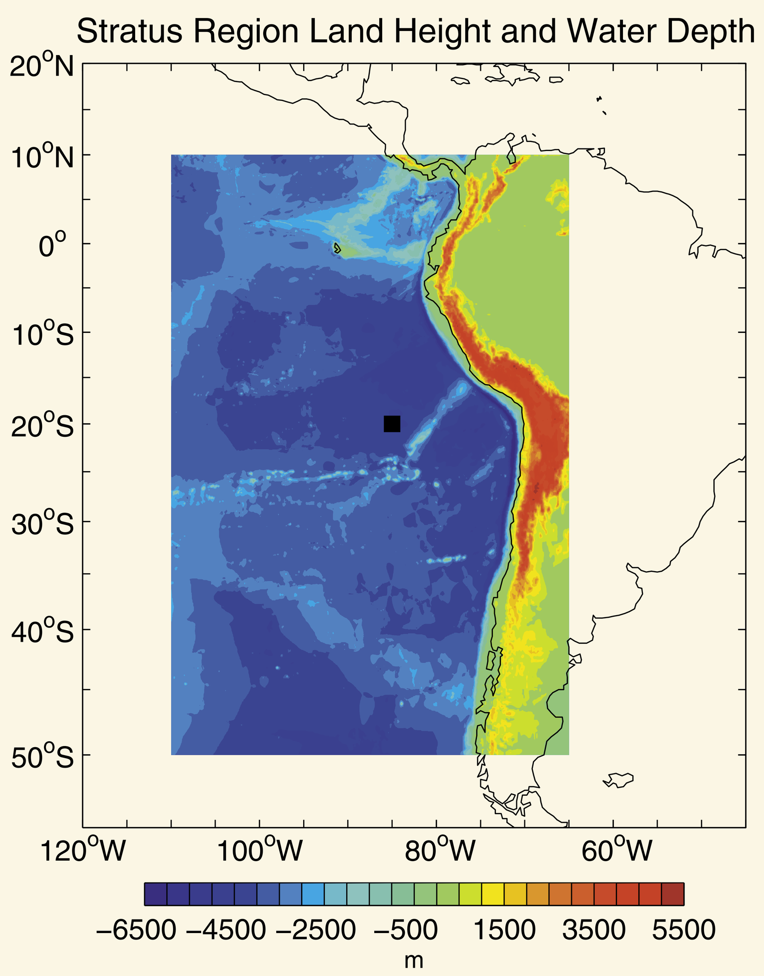
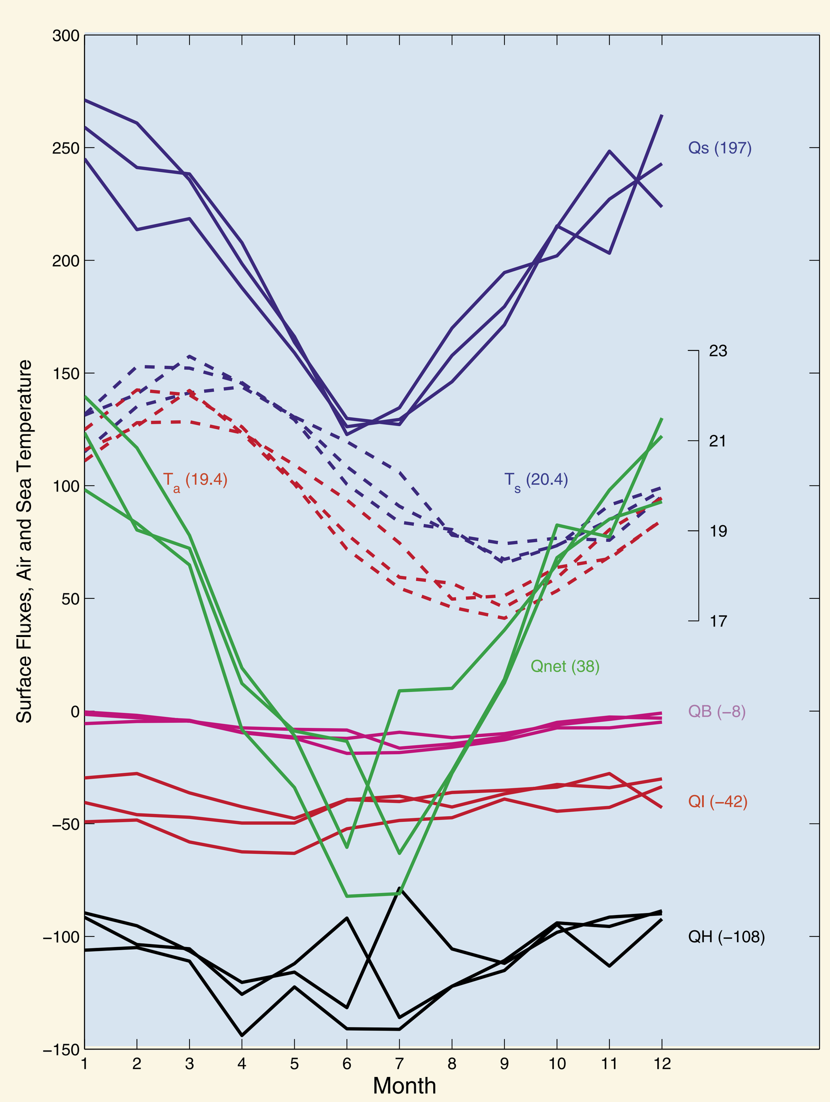


Figure #1: The location of the Stratus mooring in the SouthEast subtropical Pacific Ocean. Notice the high Andes mountains in Chile and Peru which can have a significant influence on the large-scale atmospheric flow.

Surface Fluxes

For the first time, high quality surface fluxes have been measured under the stratus cloud decks. The buoy sensors undergo rigorous pre and post-calibrations, as well as in the field comparisons with shipboard sensors. All the individual measurements meet or excede WOCE standards, with an overall uncertainty in the net annual heat flux of 10 W/m^2. This data is freely available from our website (http:\\uop.whoi.edu) and is being actively used for validation by ECMWF and NCEP. The data is also being incorporated by the satellite community for algorithm development. With three years of data, we are in a good position to begin studying inter-annual variability.



The annual cycle of the heat flux components is shown in figure 1. The variability in the austral winter is dominated by synoptic weather events that influence wind speed and hence latent heat flux. Austral summer variability is dominated by the radiation terms, indicating the role of clouds.

Figure 5: Surface heat fluxes, and the air and sea surface temperatures, for the three years of data. The air and sea surface temperature axis is on the right. The heat flux components are labelled with the corresponding long term mean value in brackets (in W/m^2).

Data Overview

The mooring records surface meteorology once per minute and measures temperature, conductivity and velocity in the upper ocean at sampling periods between 3.75 and 60 minutes.

The mixed layer exhibits a shallow seasonal thermocline for much of the year, with mixing down to the thermocline occuring in late austral winter. The velocity structure is characterized by three components: a slow drift to the north-northwest (as part of the gyre scale circulation), a surface Ekman transport, and an eddy field. Note that the eddy velocities have some shear between the thermocline (128m), the deep layer (350m) and the surface layers (10 and 20m). The meteology exhibits much high frequency structure, but we can see persistent features such as the thinning of the stratus clouds in the afternoon, and the subsequent change in the two components of radiation.

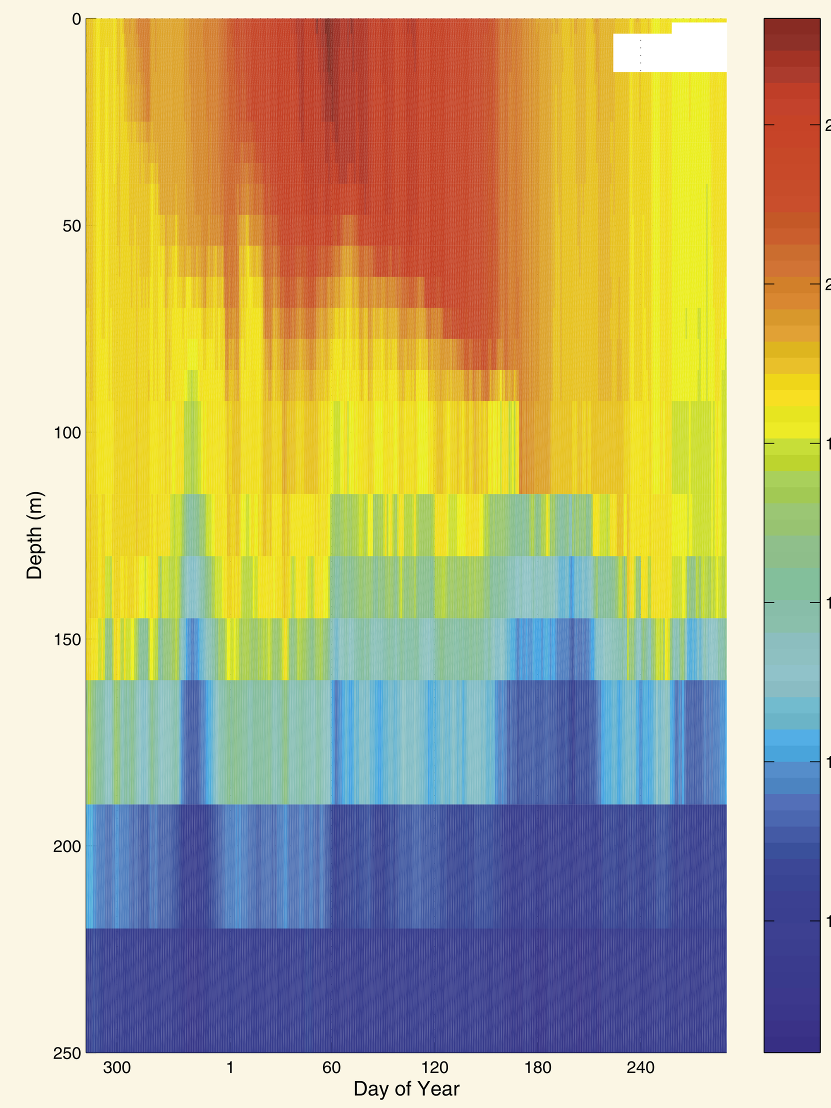


Figure 2: The temperature record for the first year of deployment. Note the strong seasonal thermocline, and alsothe two episodic shoalings of the main thermocline which are indicative of cold eddies.

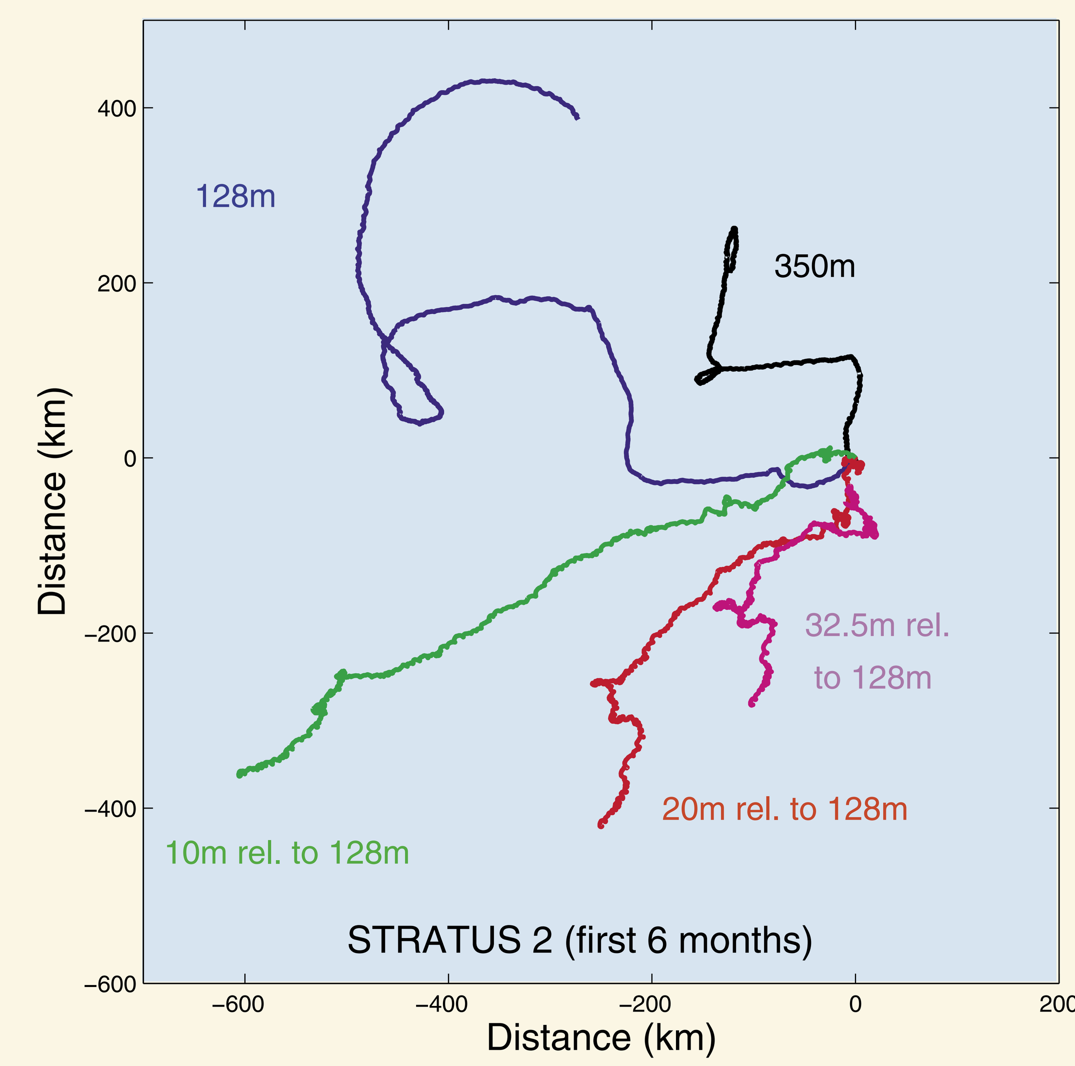


Figure 3: Progressive vector diagrams from current meters at 10, 20, 32.5, 128 and 350m depth. The shallow currents are plotted relative to the thermocline (128m) currents to emphasize the Ekman transport.

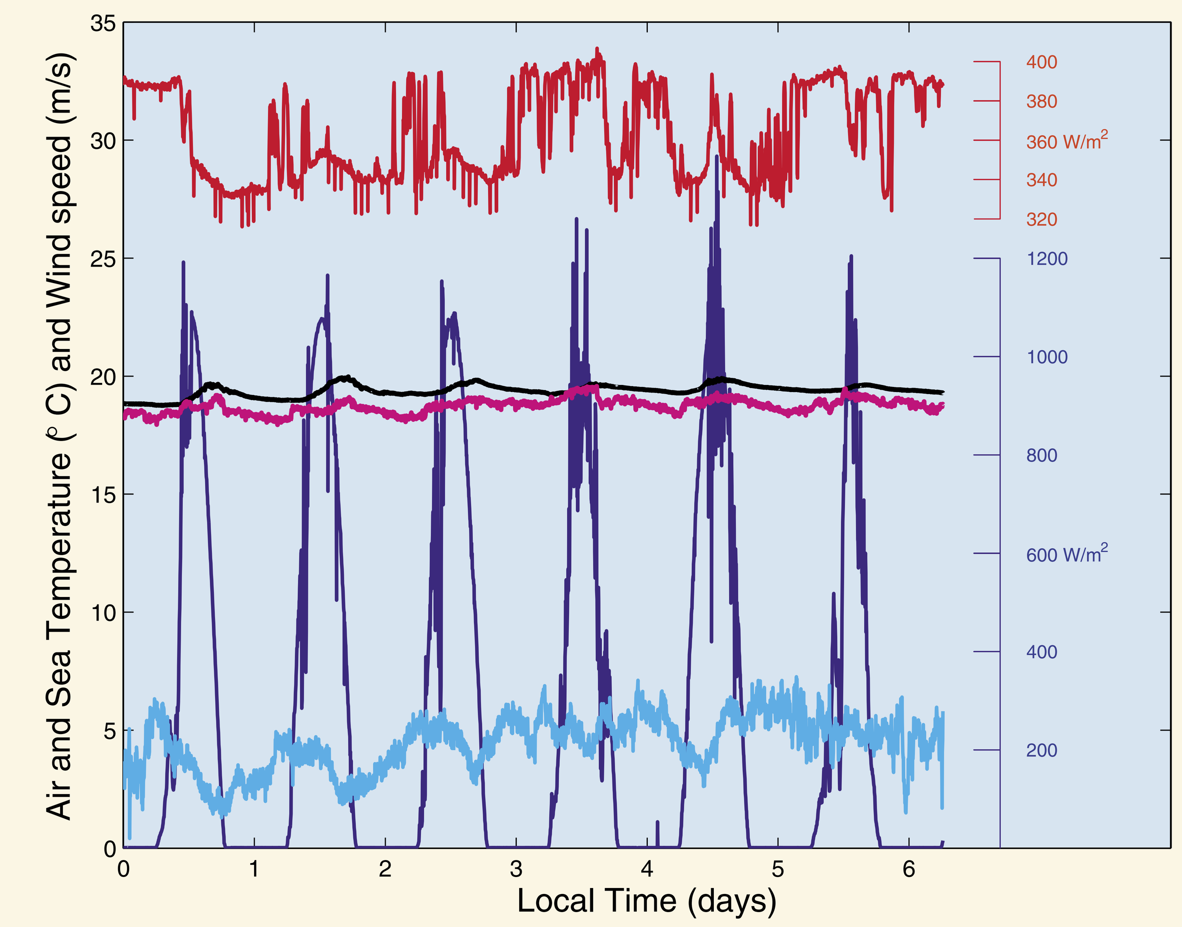


Figure 4: An example of the high quality meteorology data collected by the buoy. Note the diurnal cycle in the radiation indicating the thinning of the stratus clouds in late afternoon.

Heat and Salt Budgets

The upper ocean in this region shows a remarkable amount of frontal activity, which introduces unmeasurable small-scale horizontal gradients into the heat content equation. However, on annual time scales the back and forth advection of fronts averages out of the problem. The components of the annual budgets of heat and salt in the upper ocean are quantified in the table below (positive flux warms the ocean or increases the salinity). The large uncertainty in surface fluxes is not an indication of measurement error but rather inter-annual varaibility. Other uncertainties are dominated by error terms.

	Surface Flux	Ekman Transport	Geostrophic Transport	Ekman Pumping	Eddy Flux Divergence	Vertical Diffusion
Annual Heat Fluxes (W/m^2)	38 ± 15	0 ± 2	-15 ± 4	32 ± 2	-25 ± 20	-1 ± 0.5
Annual Salt Fluxes (psu m)	46 ± 5	4 ± 2	-44 ± 7	25 ± 3	-35 ± 25	0 ± 0.5

Strong sources of heat and salt at the surface are reinforced by the convergent Ekman flow and are balanced by cool (and fresh) advection of the large-scale gyre, and by a divergent eddy flux. The advection of heat (or salt) by the Ekman transport is negligible, at our mooring site, since the flow tends to be along mean isotherms (isohalines).

The large contribution due to an eddy flux divergence is unexpected because the eddy kinetic energy of this area of the world's oceans is small. However, the sharp contrast between coastal upwelled water which is cold and fresh, with the warm and salty offshore water, allows for a significant fluxes. Comparisons with drifters, deployed during the mooring cruises, corroborate the size of the eddy flux.

Ongoing Work

Current work focuses on the diurnal scale fluctuations in the meteorology and the interaction of the mixed layer with the underlying low salinity water.

The diurnal signals are generally small, but correlations between the observed variables can lead to significant mean fluxes. For instance, do the observed diurnal cycles in wind speed and humidity lead to a latent heat flux that is greater than that expected from the daily averages? Since, we have one minute sampling, we will decompose the surface fluxes by frequency. This is important for climate models since it indicates how much of the flux is potentially lost with a coarse time step.

The region near the buoy forms a highly saline mode water that can be tracked onto the equator, where it enters the current system near the core of the Equatorial Undercurrent. Immediately below the thermocline is a low salinity water mass. The inter-annual variability in these two water masses and the potential processes by which they communicate is an ongoing area of interest. The current mooring has increased resolution across and below the thermocline so as to address the role of double diffusion.

The three years of data will also give us a good baseline against which to compare any deviations which may arise during the next El Nino/La Nina event.

Acknowledgements

The instrument and mooring preparation at WHOI involves many people including Jeff Lord, Paul Bouchard, Jason Smith, Dick Payne and Rick Trask. The field work has been carried out aboard the R/V *Ron H. Brown* and the R/V *Melville*. The cruise work has also been aided by many people at the University of Concepcion, Chile and at the Servicio Hydrografico y Oceanografico de la Armada, Chile including Jaime Letelier and Oscar Pizarro.